Nuove sfide della fisica applicata alla radioterapia

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ComingSoon
1956

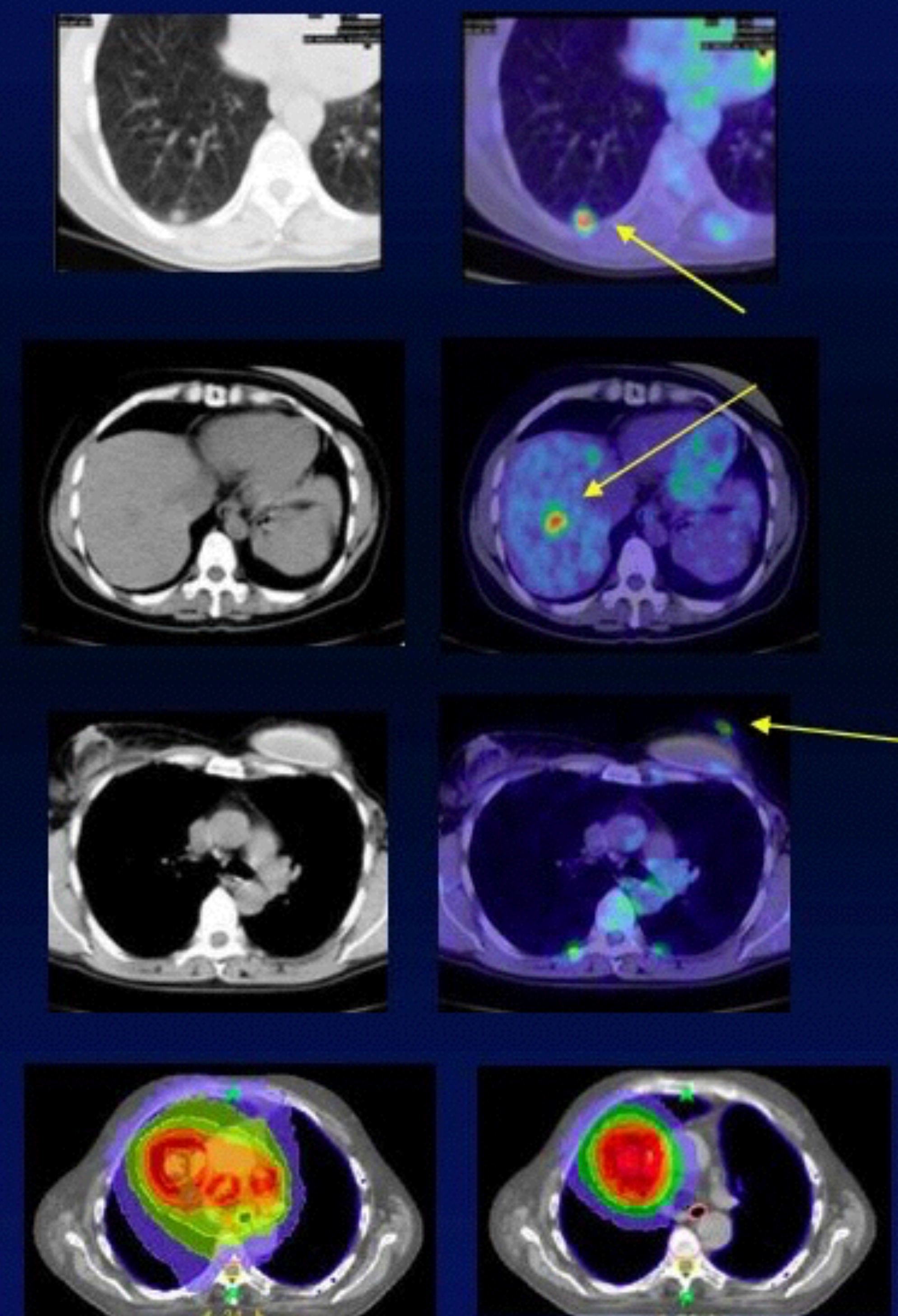
Published in final edited form as:
Radiat Res. 2012 April ; 177(4): 436–448.

Application of Metabolic PET imaging in radiation oncology

Metabolic PET can provide information that impacts radiotherapy planning in several ways. First, PET may detect a tumor that is missed by CT or MRI. Second, PET may detect additional tumor regions outside the tumor volume as defined by CT or MR imaging. Third, PET may show subregions or foci with increased or altered metabolism within the gross tumor volume that could be preferentially targeted and treated with escalated radiation doses. The more precise 3D delineation of tumor volumes could translate into improved locoregional control with radiation therapy. A common issue in the use of FDG-PET for the delineation of radiation target volumes is the definition of a standardized uptake value (SUV) threshold for involved disease. There is no consensus definition of what constitutes metabolically active tumor as a function of SUV, and the definition of target volumes on PET is somewhat arbitrary. Generally, in order to define the metabolic target volume, contours based on multiple SUV thresholds are generated, and the radiation oncologist subsequently chooses the threshold that is believed to most accurately represent the burden of disease as determined by clinical exam and/or other imaging modalities. Contours from

IMPATTO DIAGNOSTICA:

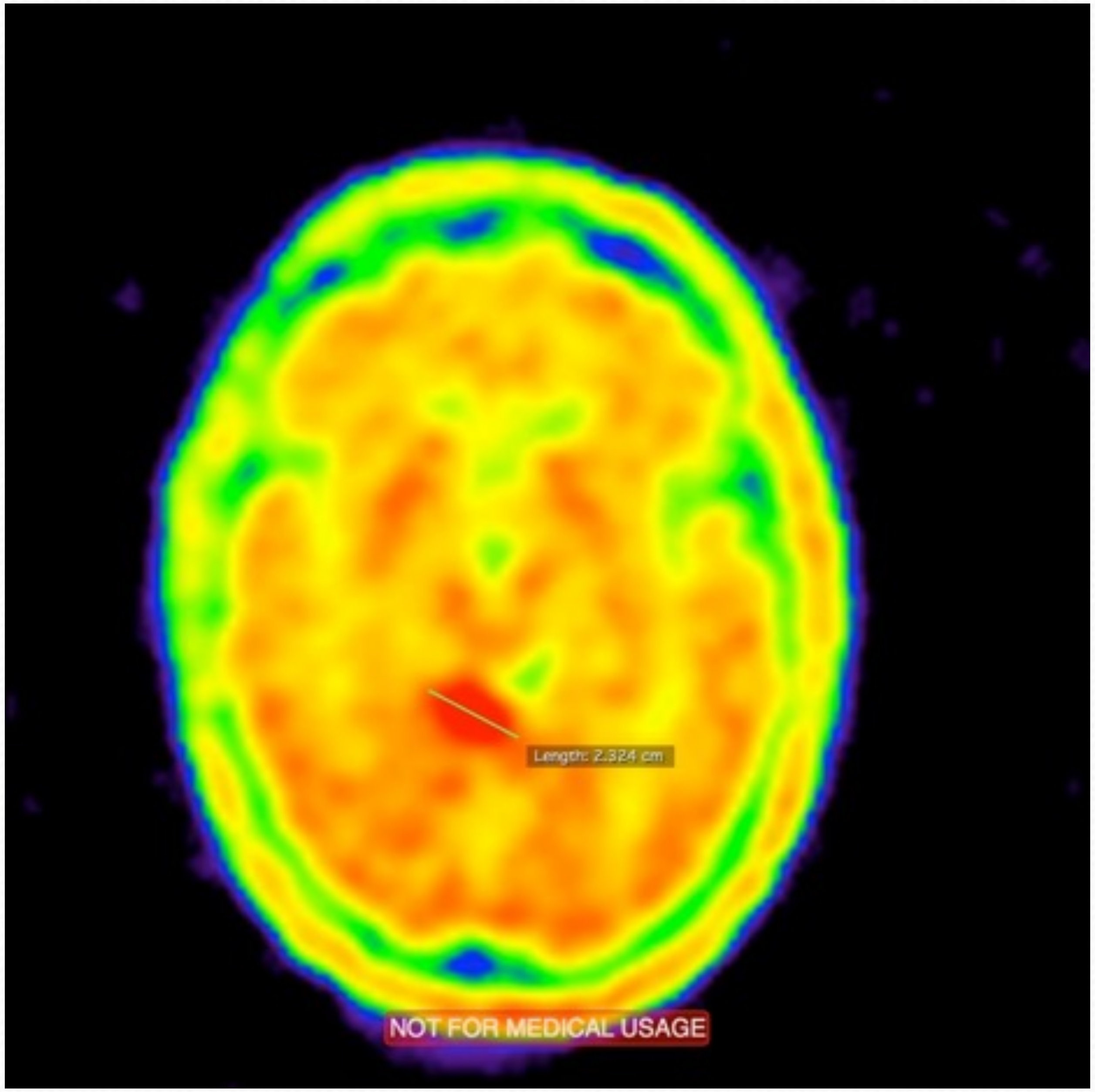
- Diagnosi
- Stadiazione
- Ristadiazione e follow-up
- Radioterapia



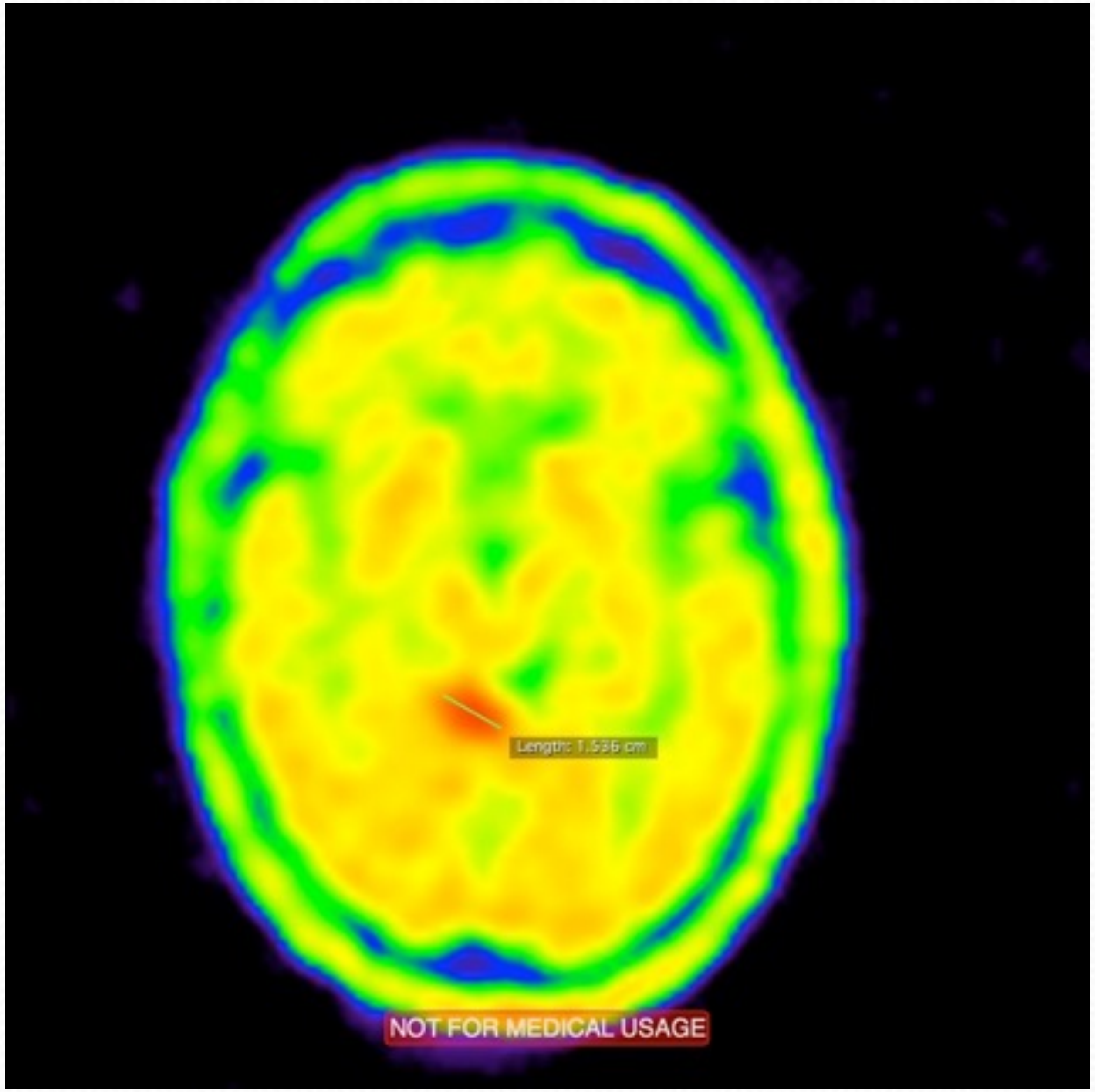
Metodo	Vantaggi	Limitazioni
Manuale	*Semplice da usare*	*Operatore dipendente, suscettibile alla scala di colore e time consuming*
SUV>2.5	*Semplice da implementare ed ad alta efficienza*	*Assunzione: SUV > 2.5 FALSO !!!*
Soglia 40%	*Semplice da implementare ed ad alta efficienza*	*Sensibile agli artefatti, al rumore e all'eterogeneità della lesione*
Soglia ponderale	*Tiene conto del volume anatomico e del contrasto*	*Richiede un significativo sforzo nella calibrazione dei dati mediante esperimenti su fantocci*
Gradiente	*Il valore del gradiente aumenta ai bordi della lesione (variazione di intensità tra lesione e sfondo)*	*Molto sensibile al rumore*

Length: 2,32 cm

Length: 1,53 cm



VS

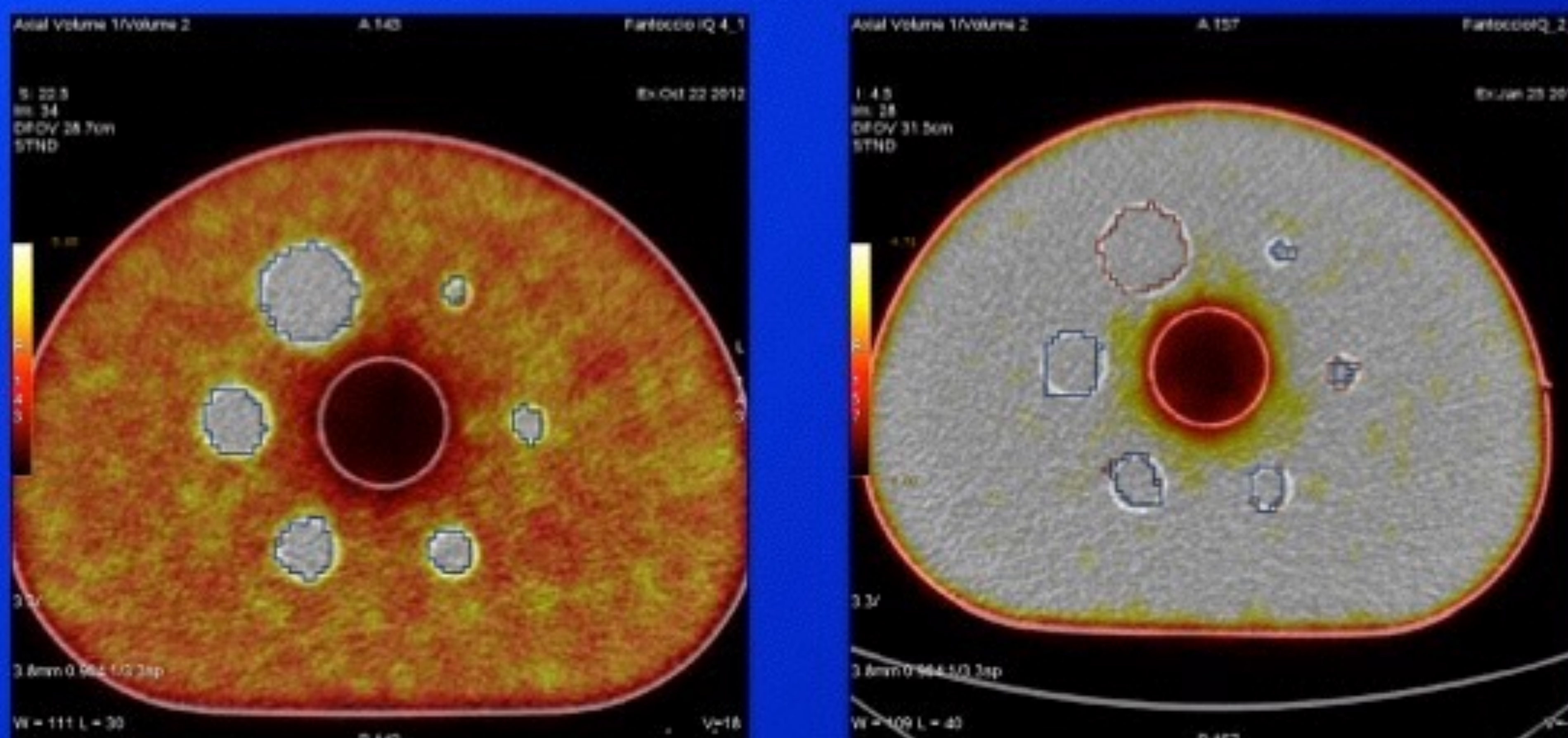


Studio su fantoccio

Variazione soglia % e fattore ponderale "w" in funzione del volume delle sfere e dei differenti S/B per ottenere il $\Delta V\%_{min}$.

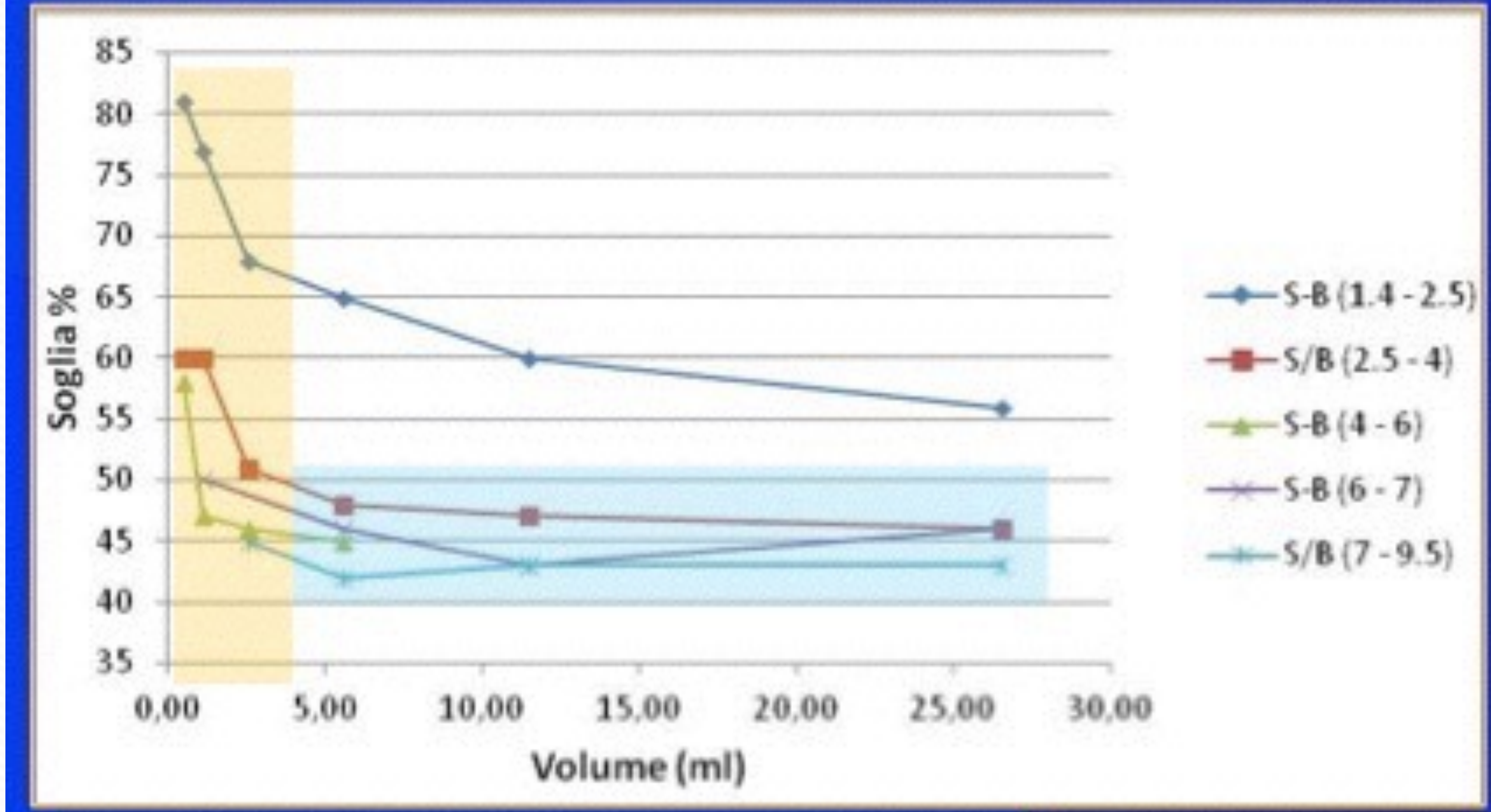
$$\Delta V\% = 100 * \left(\frac{Volume\ misurato - Volume\ noto}{Volume\ noto}\right)$$

- *Max % threshold*
- *Estimated threshold*



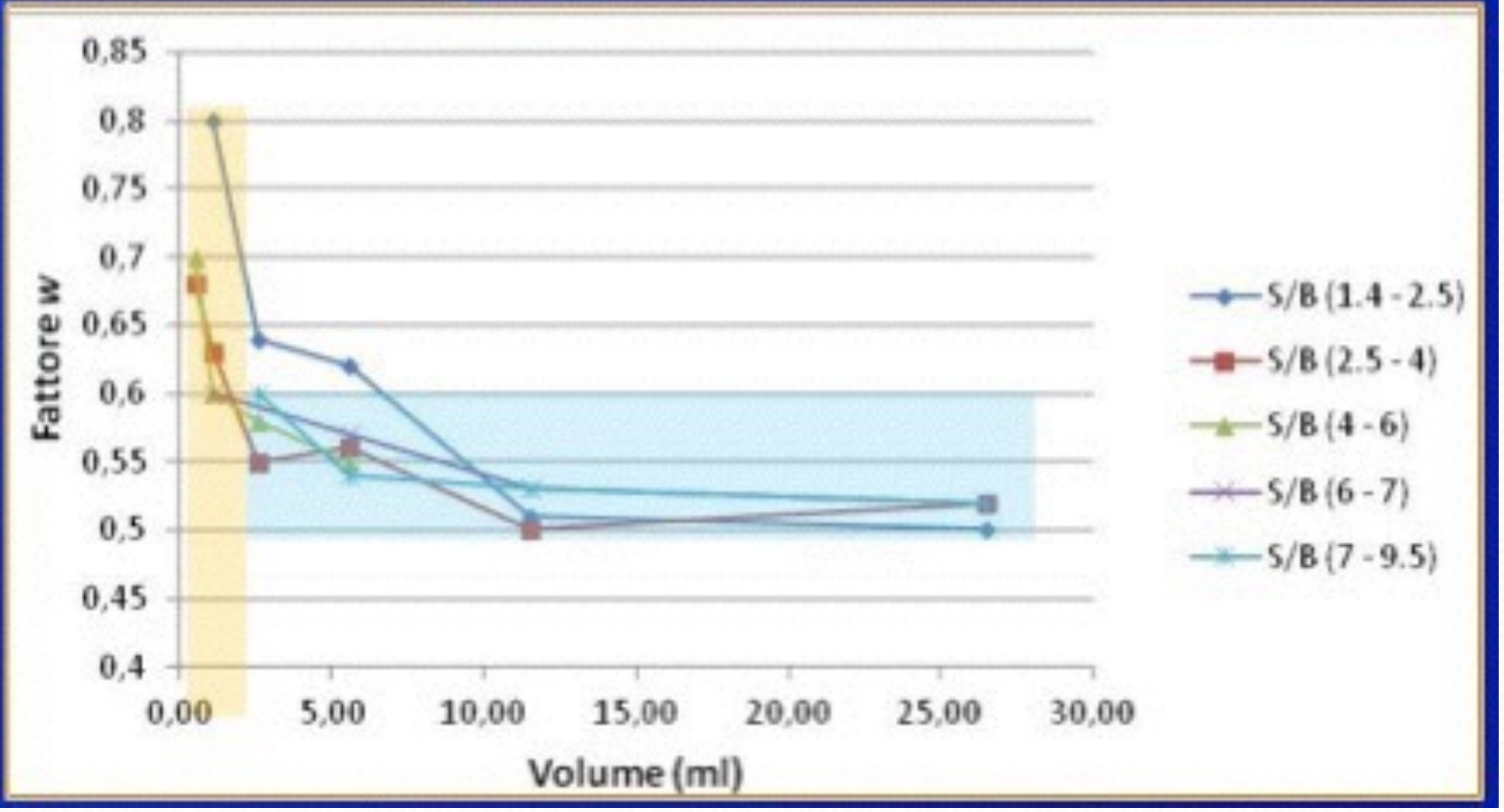
grazie a Daniele Sardina

Risultati: studio su fantoccio



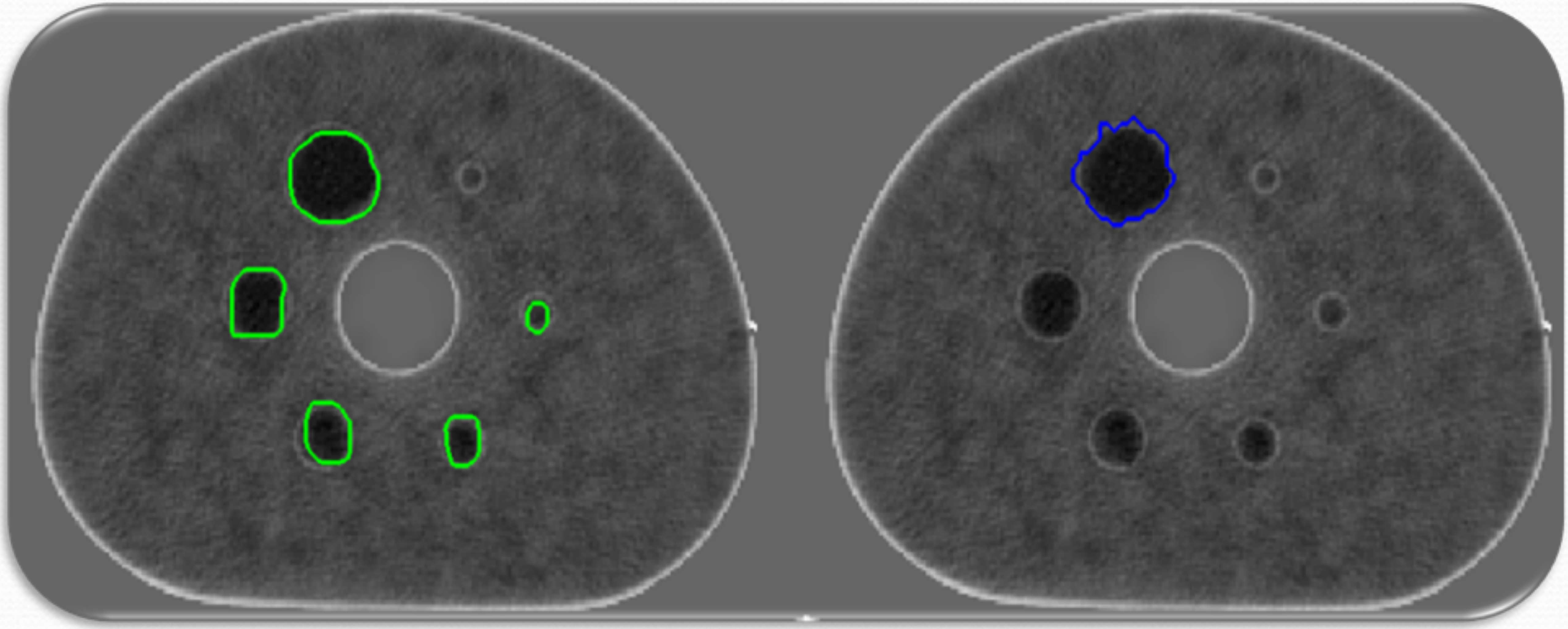
- Dipendenza non lineare dal volume e dai rapporti S/B
- V < 4ml e S/B < 2.5 → nessuna soglia fissa
- V ≥ 4 ml e S/B ≥ 2.5 → soglia % ottimale ϵ [40 – 50]%

- Dipendenza non lineare dal volume e dai rapporti S/B
- V < 2ml e S/B < 2.5 → nessuna soglia fissa
- V ≥ 2 ml e S/B ≥ 2.5 → fattore w ottimale ϵ [0.5 – 0.6]



grazie a Daniele Sardina

Risultati



Segmentazione delle sfere di un fantoccio con un contrasto di 1.5-2:

(a) RWg DSC = 0.952±0.045 (mediata su 5 sfere)
(b) RG DSC = 0.921 (sfera con diametro di 3.7 cm)

A. Stefano, et al. A Graph-Based Method for PET Image Segmentation in Radiotherapy Planning: A Pilot Study, in A. Petrosino, ed., Image Analysis and Processing - ICIAP 2013: LNCS, v. 8157, Springer Berlin Heidelberg, p.711-720

Studio di un paziente

Negli esperimenti con **fantocci**, la dimensione PET coincide con quella CT

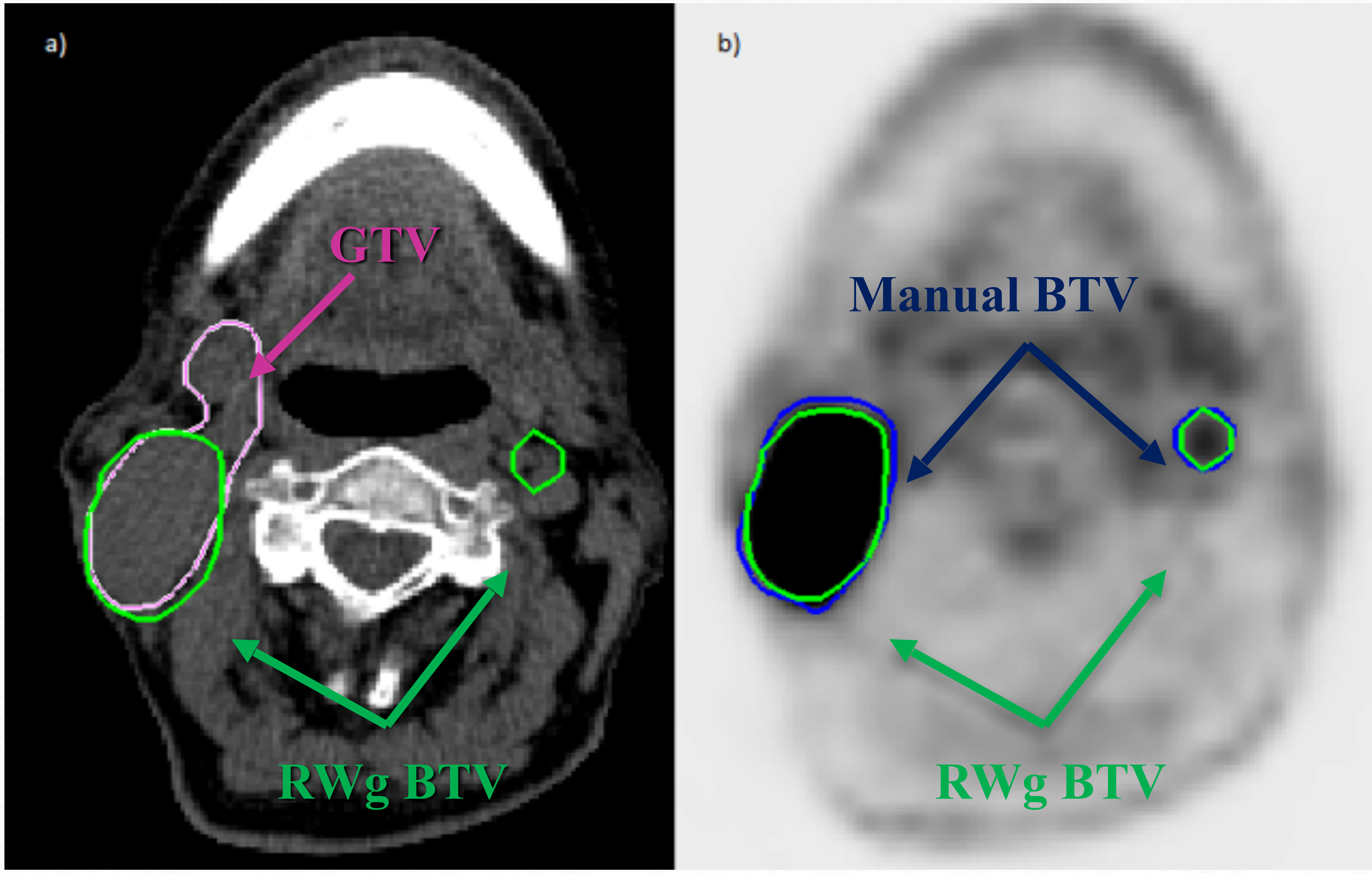
Questo non è vero negli studi con **pazienti**: il BTV può mostrare informazioni **differenti e addizionali**

La segmentazione manuale è fortemente operatore dipendente

Il BTV cambia radicalmente il piano di trattamento

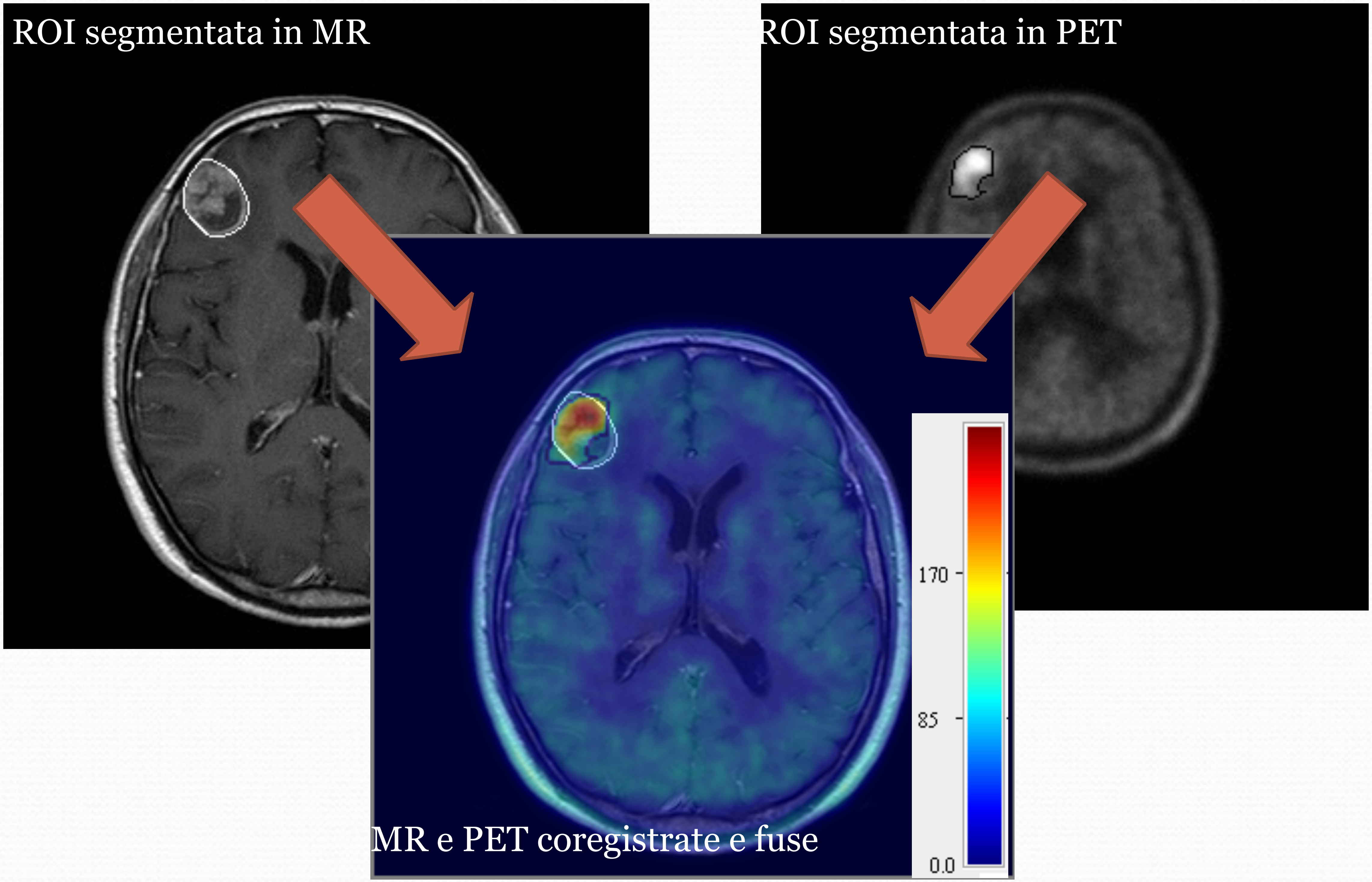
Il BTV è esterno al GTV poichè non visibile in CT

La segmentazione con RW è real-time (1.4 seconds)



A. Stefano, et al. A Graph-Based Method for PET Image Segmentation in Radiotherapy Planning: A Pilot Study, in A. Petrosino, ed., Image Analysis and Processing - ICIAP 2013: LNCS, v. 8157, Springer Berlin Heidelberg, p.711-720

Complementarietà delle metodiche RM e PET

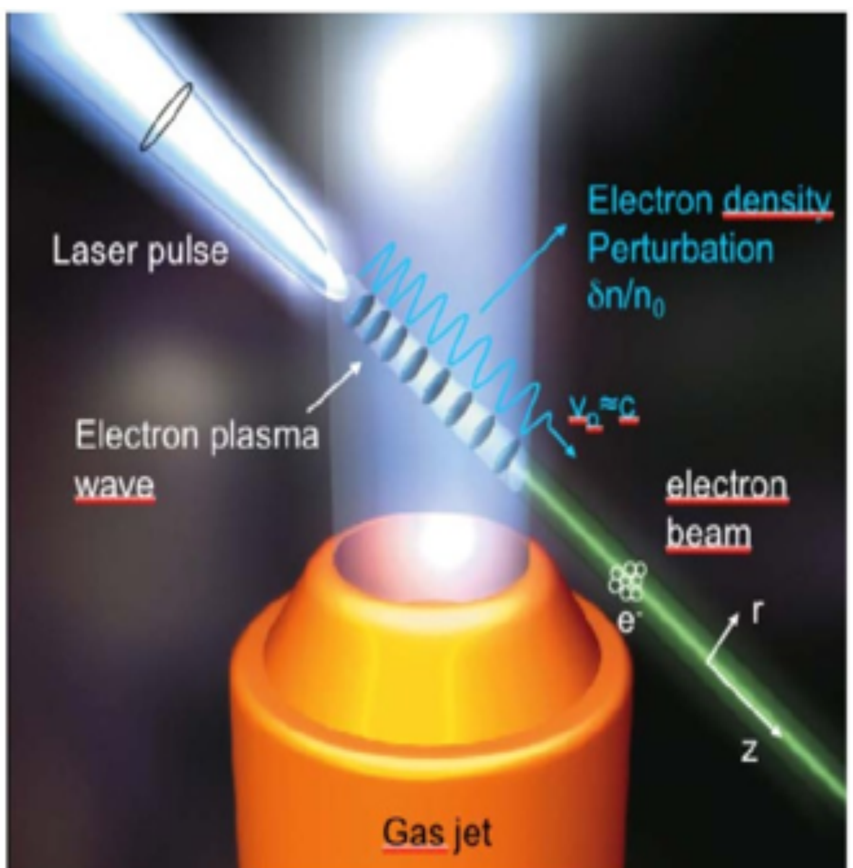


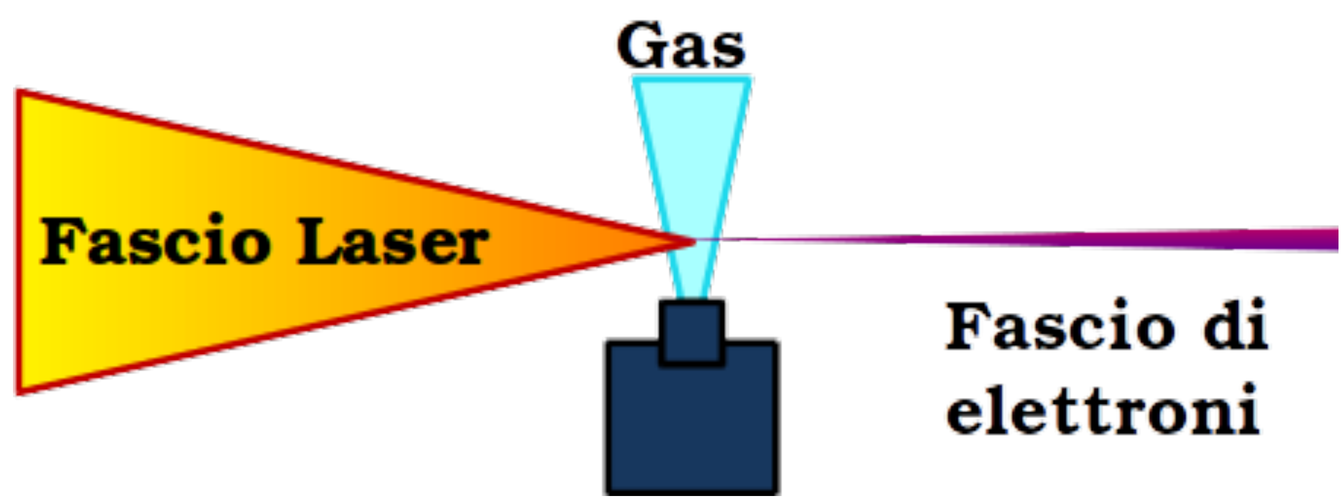
VOLUME 43, NUMBER 4 PHYSICAL REVIEW LETTERS 23 JULY 1979

Laser Electron Accelerator

T. Tajima and J. M. Dawson
Department of Physics, University of California, Los Angeles, California 90024
(Received 9 March 1979)

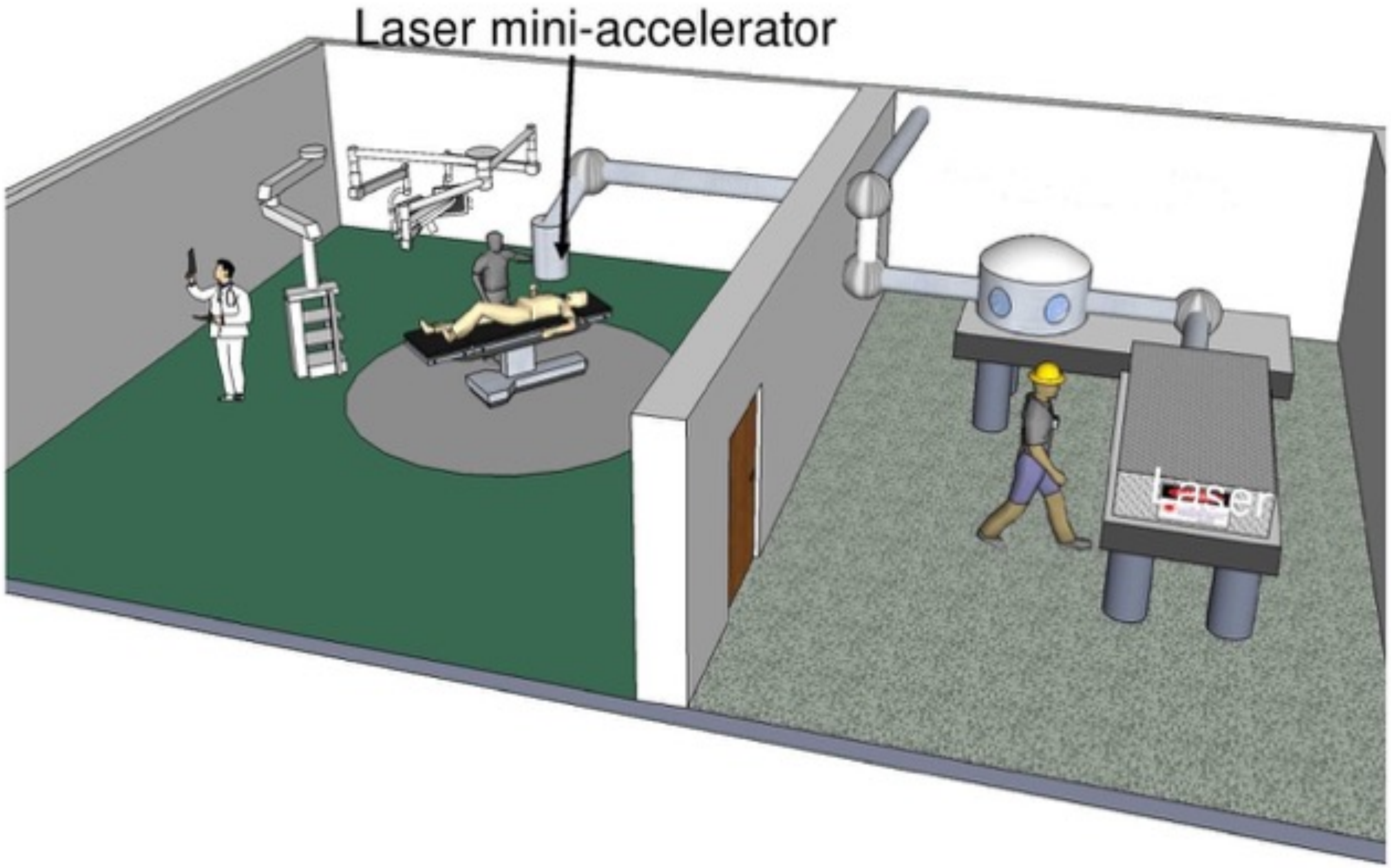
An intense electromagnetic pulse can create a weak of plasma oscillations through the action of the nonlinear ponderomotive force. Electrons trapped in the wake can be accelerated to high energy. Existing glass lasers of power density 10^{18}W/cm^2 shone on plasmas of densities 10^{18} cm^{-3} can yield gigaelectronvolts of electron energy per centimeter of acceleration distance. This acceleration mechanism is demonstrated through computer simulation. Applications to accelerators and pulsers are examined.

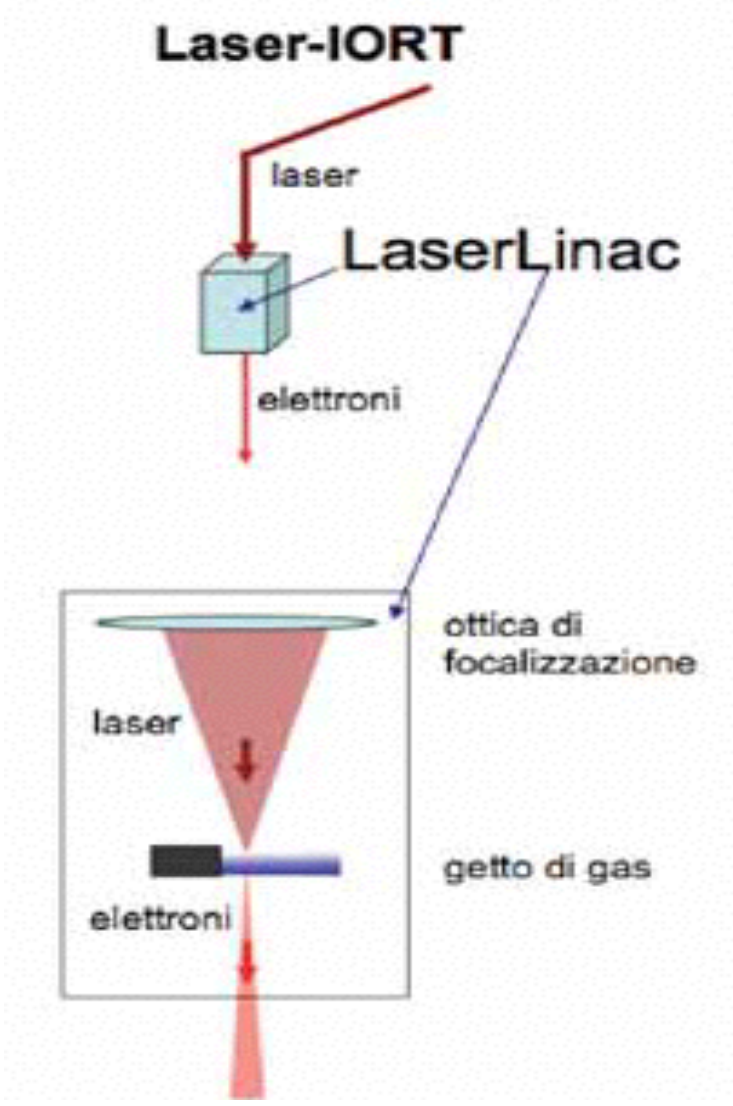




Vantaggi di un acceleratore LASER-driven

- Minori costi di manutenzione
- Ridotte dimensioni in sala operatoria
- Un solo laser può servire più sale operatorie



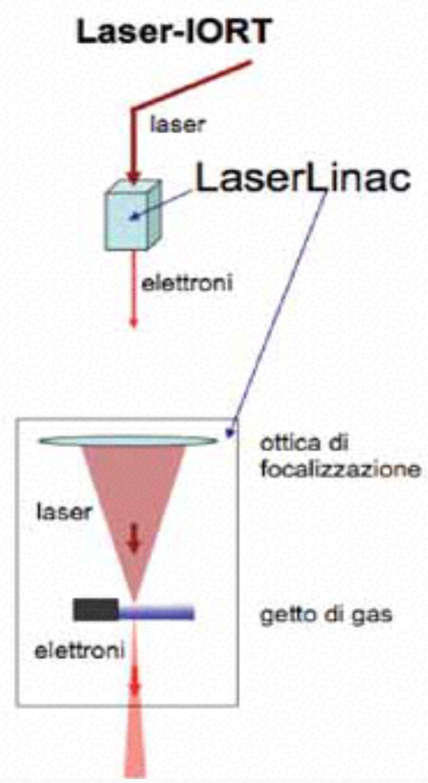


Acceleratori commerciali vs Laser-IORT

AIP | Proceedings

LaserIORT: a laserdriven source of relativistic electrons suitable for IntraOperative Radiation Therapy of tumors

A. Gamucci, N. Bourgeois, T. Ceccotti, X. Davoine, S. Dobosz, P. D'Oliveira, M. Galimberti, J. Galy, A. Giulietti, D. Giulietti, L. A. Gizzi, D. J. Hamilton, L. Labate, E. Lefebvre, J. R. Marquès, P. Monot, H. Popescu, F. Réau, G. Sarri, P. Tomassini, and Ph. Martin



NOVAC7

LIAC

$$D_{Laser} \cong 7cGy/impulso$$

Prestazione	NOVAC7 (HITESIS SpA)	LIAC (SORDINA SpA)	Laser-IORT (sperimentale)
Energia cinet. max	≤ 9 MeV	≤ 12 MeV	≤ 50 MeV
Energie disponibili	3,5,7,9 MeV	4,6,9,12 MeV	2-50 MeV
Carica per pacchetto	6 nC	1.8 nC	1.6 nC
Frequenza di ripetiz.	5 Hz	5-20 Hz	10 Hz
Corrente media	30 nA	18 nA (a 10 Hz)	16 nA
Durata pacchetto	4 μs	1.2 μs	< 1 ps
Corrente di picco	1.5 mA	1.5 mA	> 1.6 KA

RBE???

(Giulietti A. et al, Fisica in Medicina n. I/2 – 2012)

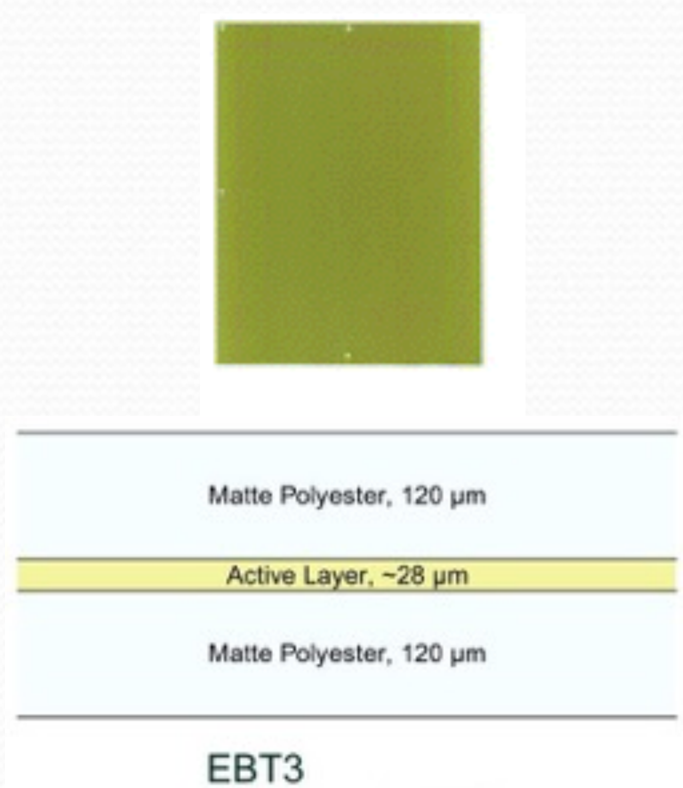
Caratterizzazione dosimetrica

<u>Problematiche di ricerca di un sistema laser-driven</u>

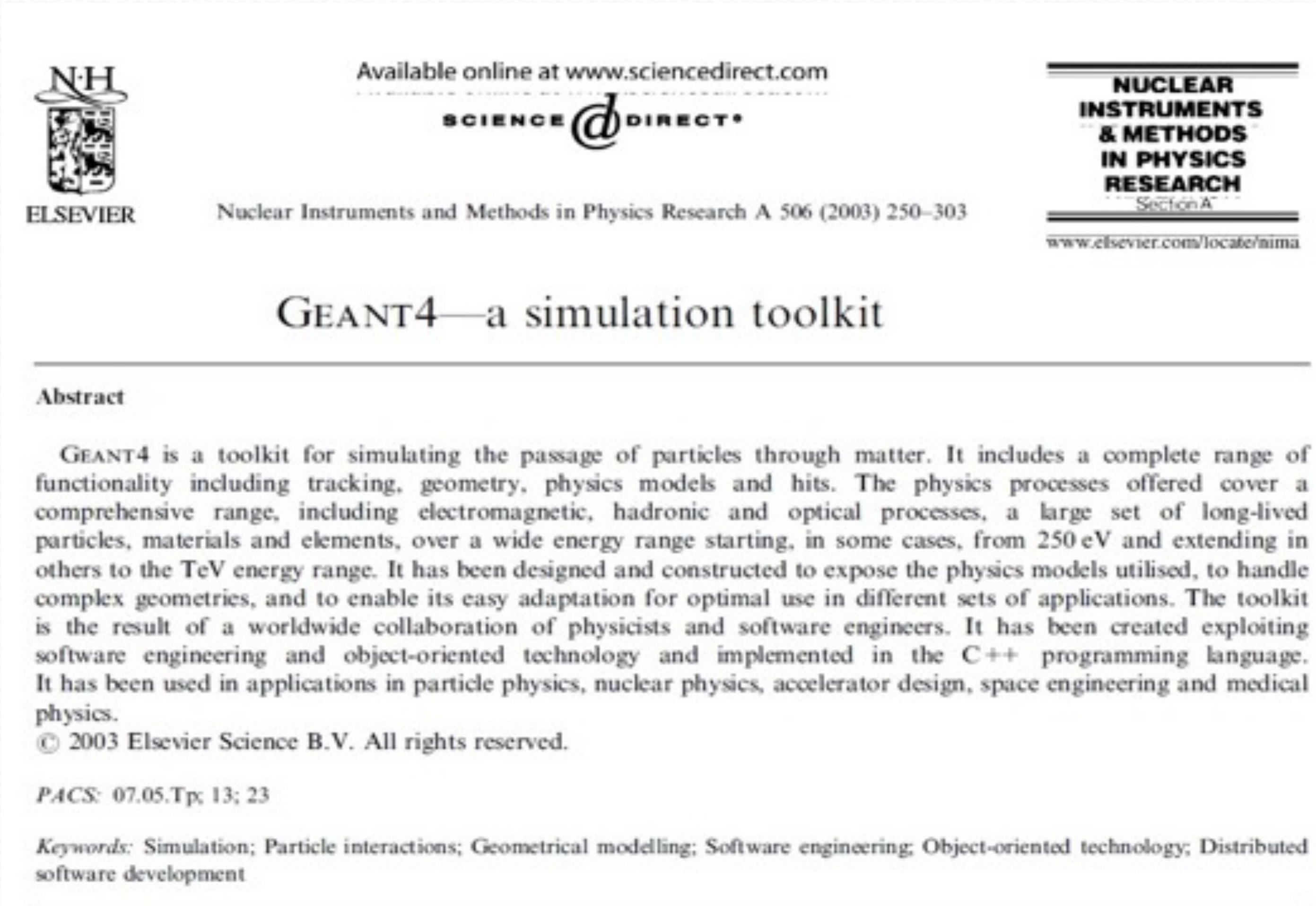
- Non esistono protocolli dosimetrici
- Elevato dose-rate → non possono essere utilizzati rivelatori standard per dosimetria assoluta
- Ampio spettro energetico
- Errore di ripetibilità ≅ 10% (contro < 3% per gli acceleratori commerciali)
- Effetti radiobiologici ancora non studiati

<u>Strumenti per la caratterizzazione dosimetrica</u>

- Misure sperimentali con dosimetri GafChromici



- Simulazioni Monte Carlo



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Nuclear Instruments and Methods in Physics Research A 506 (2003) 250–303
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A
www.elsevier.com/locate/nima

GEANT4—a simulation toolkit

Abstract

GEANT4 is a toolkit for simulating the passage of particles through matter. It includes a complete range of functionality including tracking, geometry, physics models and hits. The physics processes offered cover a comprehensive range, including electromagnetic, hadronic and optical processes, a large set of long-lived particles, materials and elements, over a wide energy range starting, in some cases, from 250 eV and extending in others to the TeV energy range. It has been designed and constructed to expose the physics models utilised, to handle complex geometries, and to enable its easy adaptation for optimal use in different sets of applications. The toolkit is the result of a worldwide collaboration of physicists and software engineers. It has been created exploiting software engineering and object-oriented technology and implemented in the C++ programming language. It has been used in applications in particle physics, nuclear physics, accelerator design, space engineering and medical physics.

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PACS: 07.05.Tp; 13; 23

Keywords: Simulation; Particle interactions; Geometrical modelling; Software engineering; Object-oriented technology; Distributed software development

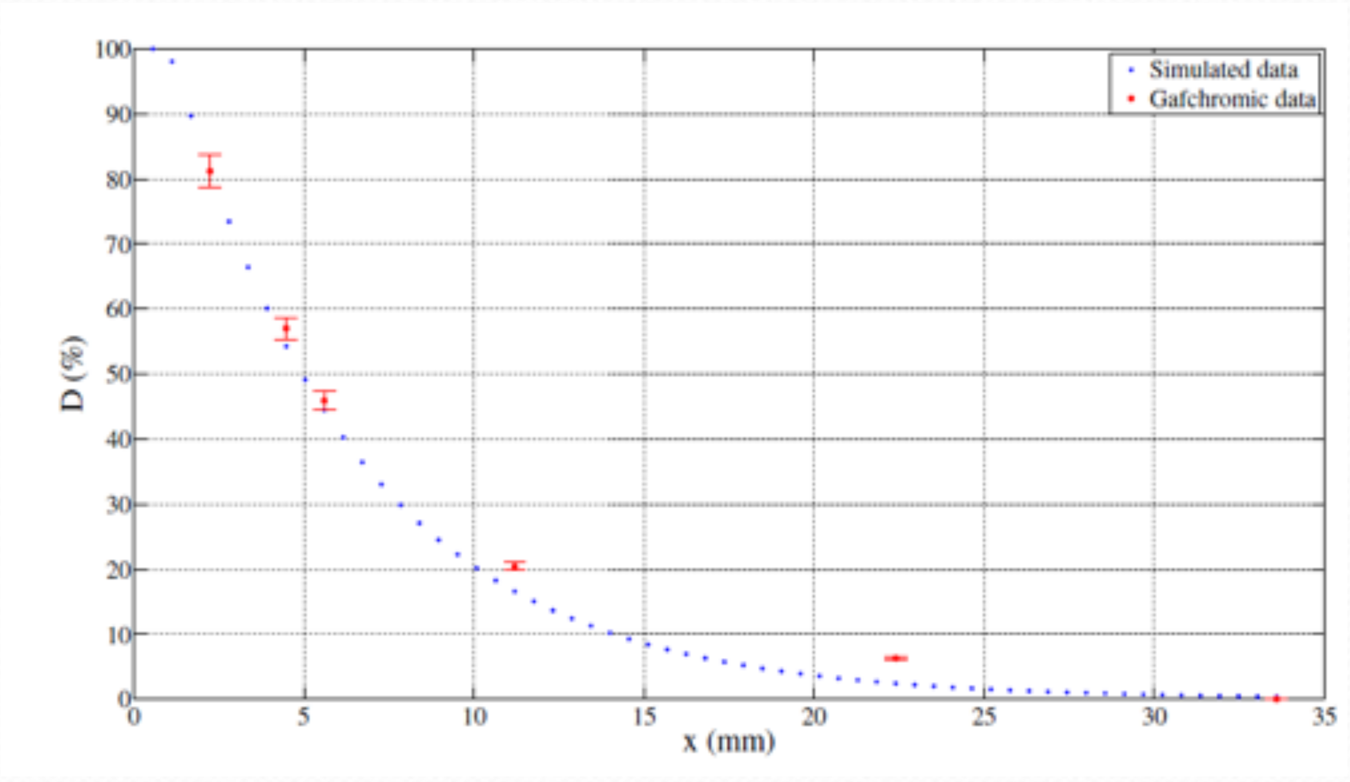
Spettro energetico

- Acceleratori commerciali: distribuzione energetiche gaussiane piccate in 4-6-8-10 MeV

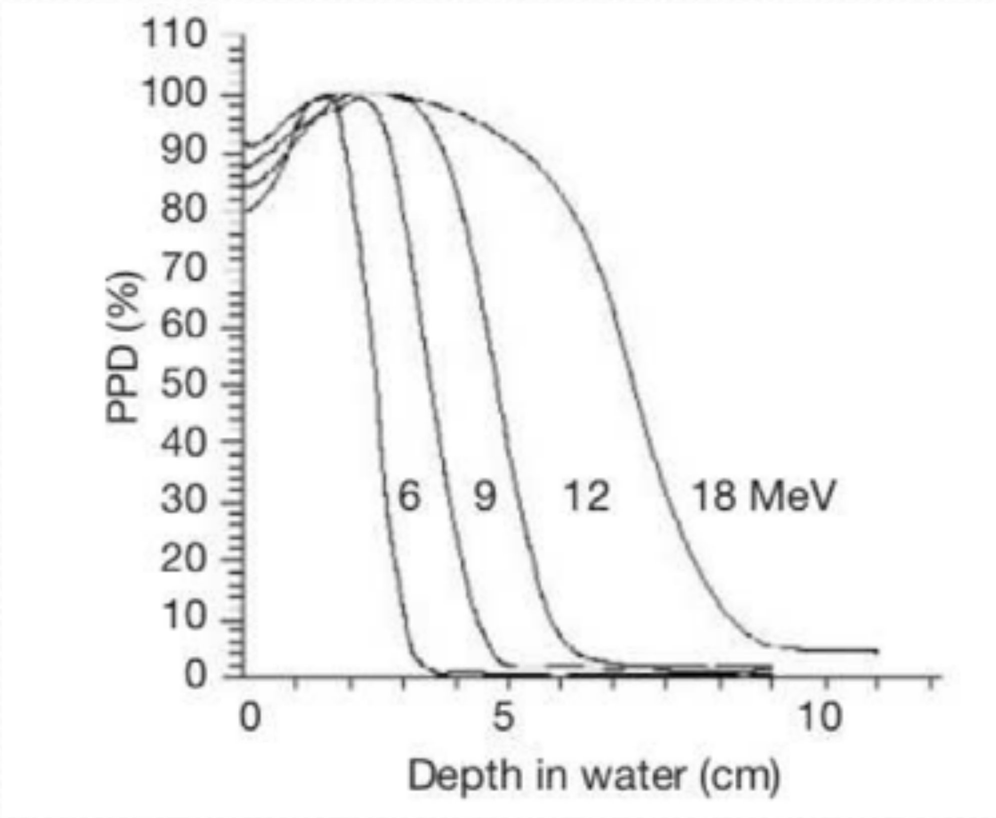
- Acceleratore laser-driven: distribuzione esponenziale con energie da 1-30 MeV

<u>Differenza tra le curve PDD</u>

PDD laser-driven



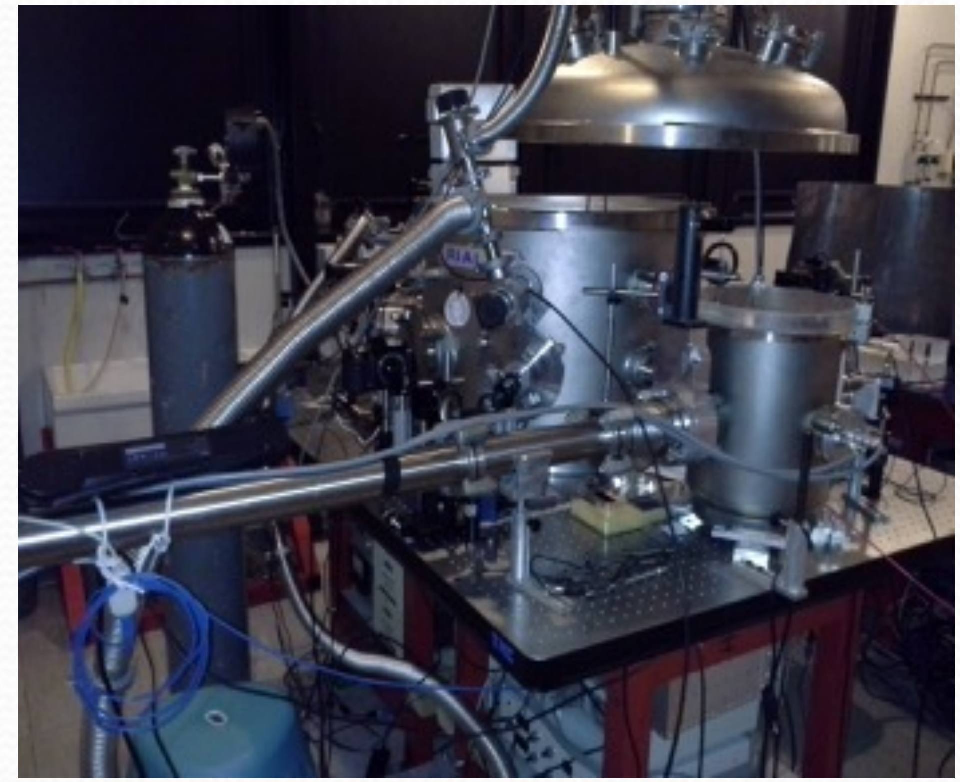
PDD NOVAC7

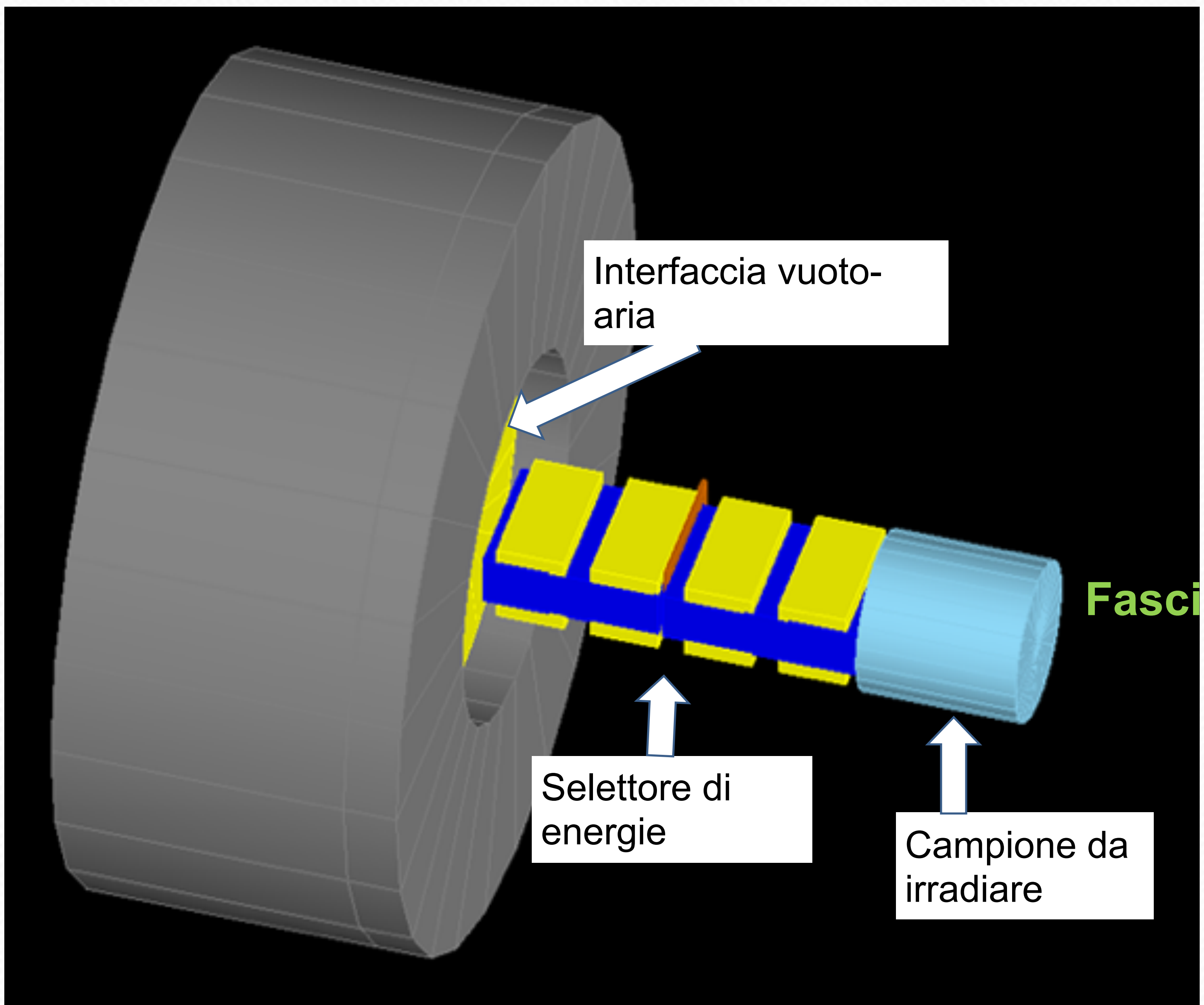


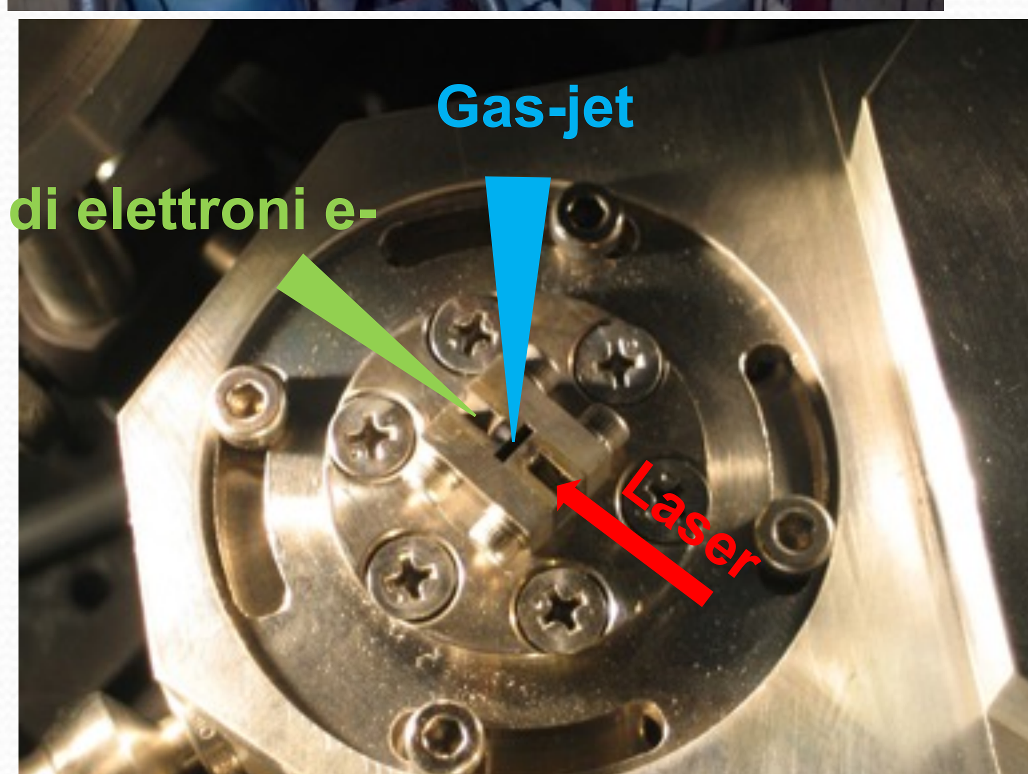
<u>Necessità di un selettore di energie</u>

Costruzione del selettore in GEANT4

Acceleratore di elettroni
Laser-driven installato presso CNR INO - Pisa







Primi irraggiamenti cellulari

Linea cellulare MCF7
carcinoma mammario
→ Primi risultati biologici!